N87-17160

SIR-B MEASUREMENTS AND MODELING OF VEGETATION

Fawwaz T. Ulaby and M. Craig Dobson
University of Michigan
Ann Arbor, Michigan

I. INTRODUCTION

This paper presents a summary of the results derived from analysis of six SIR-B data takes over an agricultural test site in west-central Illinois. The first part of the paper describes the procedure used to calibrate the SIR-B imagery, the second part pertains to the observed radar response to soil moisture content, and the last part examines the information derivable from multiangle observations.

II. SIR-B CALIBRATIONS

Five calibrated receivers distributed over an area extending approximately 20 km in both range and azimuth directions were used to record the azimuth pattern of the SIR-B antenna beam for each of six shuttle passes over the test site. A typical pattern is shown in Fig. 1(a). In addition to measuring the shape of the pattern, the transmitter power-gain product P_tG_t was determined also. The values recorded by the various receivers on the six data takes were then combined to establish the range pattern of the SIR-B antenna[1].

The second objective of the calibration task was to develop a transfer function that relates the digital number DN of a given pixel to the scattering coefficient $\sigma°$ of that pixel. To this end, two types of calibration targets were used: (a) six Active Radar Calibrators (ARCs), and (b) approximately 80 distributed targets. The ratio of the signal from an ARC to that from the background pixel in which it was deployed was typically 15 dB. The distributed targets were uniform agricultural fields whose scattering coefficients were measured by calibrated truck-mounted scatterometers within ± 2 hours of the shuttle overpass. The result of this calibration study is shown in Fig. 1(b) for one of the data takes (Orbit 97.2). Another curve (with no data points shown) is given for Orbit 49.2 to indicate the level of change that existed between data takes due to changes in transmitter power.

III. SOIL-MOISTURE RESPONSE

Two predawn ascending data takes by SIR-B were used to evaluate the effect of soil moisture on the scattering coefficient. The two images were separated in acquisition date by three days and were obtained at the same local angle of incidence ($\theta = 30°$) but with opposite azimuth viewing directions.

Figures 2(a) and 2(b) show linear regressions of the scattering coefficient measured by SIR-B versus soil moisture content for bare fields and fields planted with corn, respectively. The corn plants had an average maximum height of 280 cm and an average water content of 2.12 kg/m^2. We observe that $\sigma°$ exhibits a strong sensitivity to soil moisture content for both cases. This result is not surprising when considered alone because it would imply that the canopy is quasi-transparent, but the fact that the level of the $\sigma°$ response is about 5.5 dB higher than that of the bare-soil response presents a problem. Ordinarily, a high $\sigma°$ level for corn would be attributed to volume scattering by the corn canopy, but such a strong scattering medium would also be a highly lossy medium, thereby resulting in poor sensitivity to soil moisture. This problem was resolved by modeling the canopy backscattering as the sum of three terms: (a) volume backscattering by the canopy, (b) soil backscatter attenuated by the canopy, and (c) a new term related to soil-volume interaction. This last term accounts for forward scatter by the soil followed by reflection by the stalks, as well as the inverse process. The results of this analysis [2] are shown in Fig. 3, which shows that the soil-volume interaction term is the dominant term among the three.

IV. INFORMATION FROM MULTIANGLE OBSERVATIONS

In any assessment of the information content of multiangle SIR-B observations, it is important to understand that all observations are also separated in the time domain and may be derived from distinctive azimuthal viewing geometries. Hence, composite images of multiangle observations contain information related both to sensor/scene geometric properties and to scene dynamics. The SIR-B observations of the Illinois test site consist of two ascending and four descending data takes occurring predawn and early afternoon respectively at the viewing geometrics listed in Table 1.

Table 1. SIR-B Data Takes

Data Take	Date	Local Time	Incidence Angle	Look Direction
38.1	October 7	2:25 PM	17°	NE
49.2	October 8	6:23 AM	30°	NW
54.1	October 8	2:08 PM	38°	NE
70.1	October 9	1:52 PM	50°	NE
86.1	October 10	1:34 PM	59°	NE
97.2	October 11	5:32 AM	30°	SE

The test site consists of an agricultural region of well-drained silt loams (loess) with small vertical relief. Soil moisture conditions ranged from 0.2 to 0.3 g/cm^3 over the observation period in response to a prolonged period of cloud cover with associated light rain and ground fog. Of the agricultural portion of the site, 45% had been planted to corn and 45% to soybeans; the remaining 10% primarily contained alfalfa, sorghum, and pasture. Both the corn and soybeans were generally in harvest-ready conditions and during the experimental period approximately 10% of the corn and 30% of the soybeans were harvested. Thus, approximately 5% of the agricultural area experienced a dramatic change in surface cover due to harvest/tillage operations over any 24 hour period.

An example color composite of multiangle and multidate imagery is shown in figure 4, using data obtained at the maximum, median, and minimum incidence angle limits for SIR-B. The familiar checker-board pattern of agricultural fields is displayed in a wide variety of additive colors as related to both the magnitude of radar backscatter $\sigma°$ as a function of incidence angle θ for time-constant target conditions and to field-specific tillage/harvest history over the four-day period. Unharvested corn produces a bright return at all three angles and is observed as a variety of bright additive colors wherein hue is related to subtle differences in canopy condition (biomass, stage of growth, etc.). The progress of the corn harvest can be readily mapped on a daily basis as freshly harvested corn appears as bright blue or blue-green depending upon the date of harvest. Other crop canopies appear generally dark with image brightness proportional to surface roughness and canopy biomass conditions. Fields which have been roughened by plowing or disking tend to express themselves as various shades of green, yellow, and orange and have moderate intensity depending upon the date and nature of the tillage operation. No row direction effects are observed, which is to be expected for azimuth view angles of approximately 45° with respect to crop row direction.

The effects of gentle relief and scene dynamics on stereo imaging are illustrated by figure 5. Stereo coverage was provided by the sidelap region of the two ascending data takes both at 30° incidence angle but with a 180° difference in illumination direction and a three-day time difference. Figure 5(a) shows the additive color composite of the two data takes; the image intensity for each data take has been radiometrically calibrated to $\sigma°$ via log linear transfer functions established by active radar calibrators and by truck scatterometer observations. Yellow would indicate equivalent $\sigma°$ on both dates; the generally orange hue of the image is the result of an average increase in $\sigma°$ of 2 to 3 dB over the three day period as a consequence of daily rainfall leading to a 0.05 to 0.1 g/cm^3 increase in near surface soil moisture. Since the area is not irrigated, bright red fields can only be attributed to surface roughness changes due to tillage ($\Delta\sigma°$ = 3 to 5 dB) while green areas correspond to the harvest of corn over the three-day period.

Stereo separation of the topographic effects (3° to 5° local slopes) and scene change are enhanced by differencing the magnitudes of the two calibrated images. Figure 5(b) is a pseudo-color presentation of the difference in $\sigma°$ between the two ascending data takes. The differential illumination of local slopes along both sides of drainages allow ready discrimination of the drainage network even in areas of only 10 to 20 m net relief. In addition to the field specific changes in $\sigma°$ related to changes in agronomic conditions, the regional change in $\sigma°$ is found to correlate well with the rainfall patterns recorded by an informal network of 56 gauges. Hence, appropriate filtering of calibrated change detection can yield thematic maps of agronomic changes (i.e., harvest, no change, plowing) and contour maps of soil moisture change which are more nearly independent of field specific canopy and roughness conditions.

V. CONCLUSIONS

This study demonstrated that it is possible to establish a calibration transfer function for a space SAR with an accuracy of about ± 0.9 dB. Moreover, because the SIR-B imagery wave calibrated into $\sigma°$ units, it was possible to conduct a quantitative analysis of the radar response to soil moisture and to extend theoretical models accordingly.

The use of multiangle observations -- either in incidence, azimuth, or both -- has been found to provide valuable topographic information, and change detection provides information on agronomic conditions and soil moisture variations.

In a related study involving multipolarization airborne observations made coincident with SIR-B, a model was developed relating the phase difference between HH and VV backscattered signals from corn to the dielectrics and geometric properties of the corn canopy [3].

REFERENCES

[1] Dobson, M. C., F. T. Ulaby, D. R. Brunfeldt, and D. N. Held, "External Calibration of SIR-B Imagery with Area-Extended and Point Targets," IEEE Trans. Geoscience and Remote Sensing, Vol. GE-24, No. 4, 1986.

[2] Dobson, M. C., and F. T. Ulaby, "Preliminary Evaluation of the SIR-B Response to Soil Moisture, Surface Roughness, and Crop Canopy Cover," IEEE Trans. Geoscience and Remote Sensing, July, 1986.

[3] F. T. Ulaby, D. Held, M. C. Dobson, and K. McDonald, "Relating Polarization Phase Difference of SAR Signals to Scene Properties," IEEE IGARSS Special Issue, November, 1986.

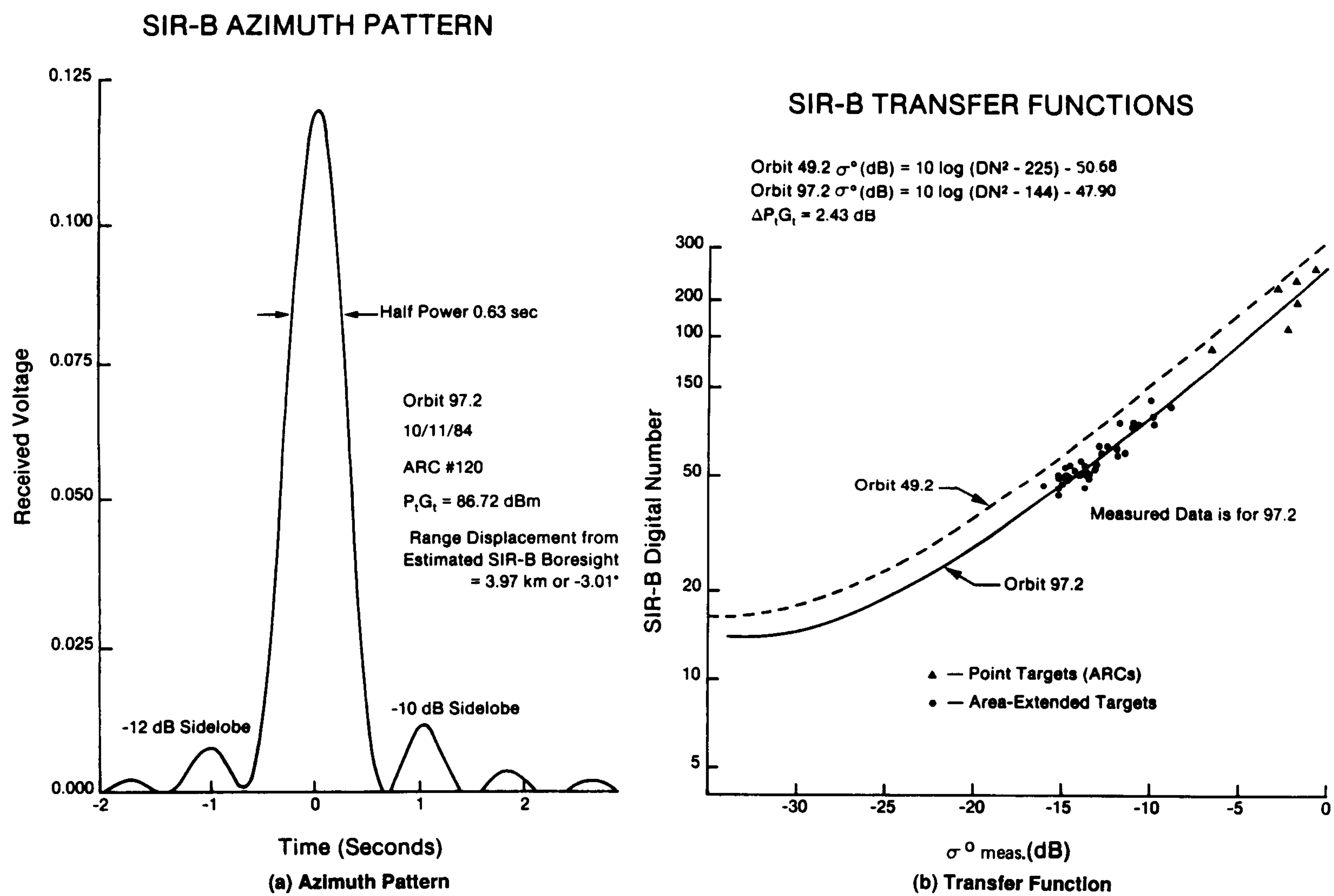


Figure 1. Measured (a) azimuth pattern of SIR-B antenna and (b) SIR-B transfer function.

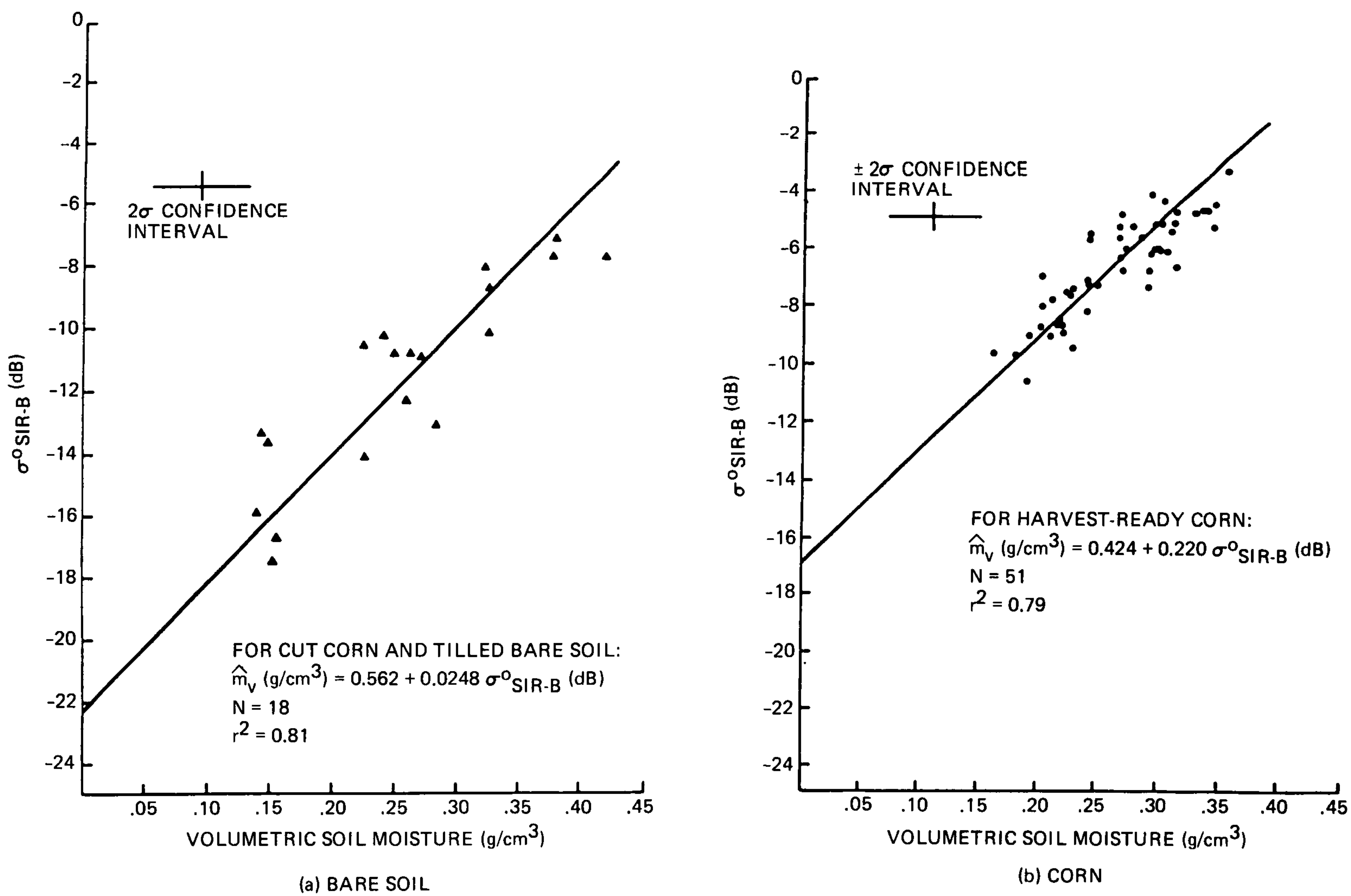


Figure 2. Measured SIR-B response to soil moisture for (a) bare soil and (b) corn canopies.

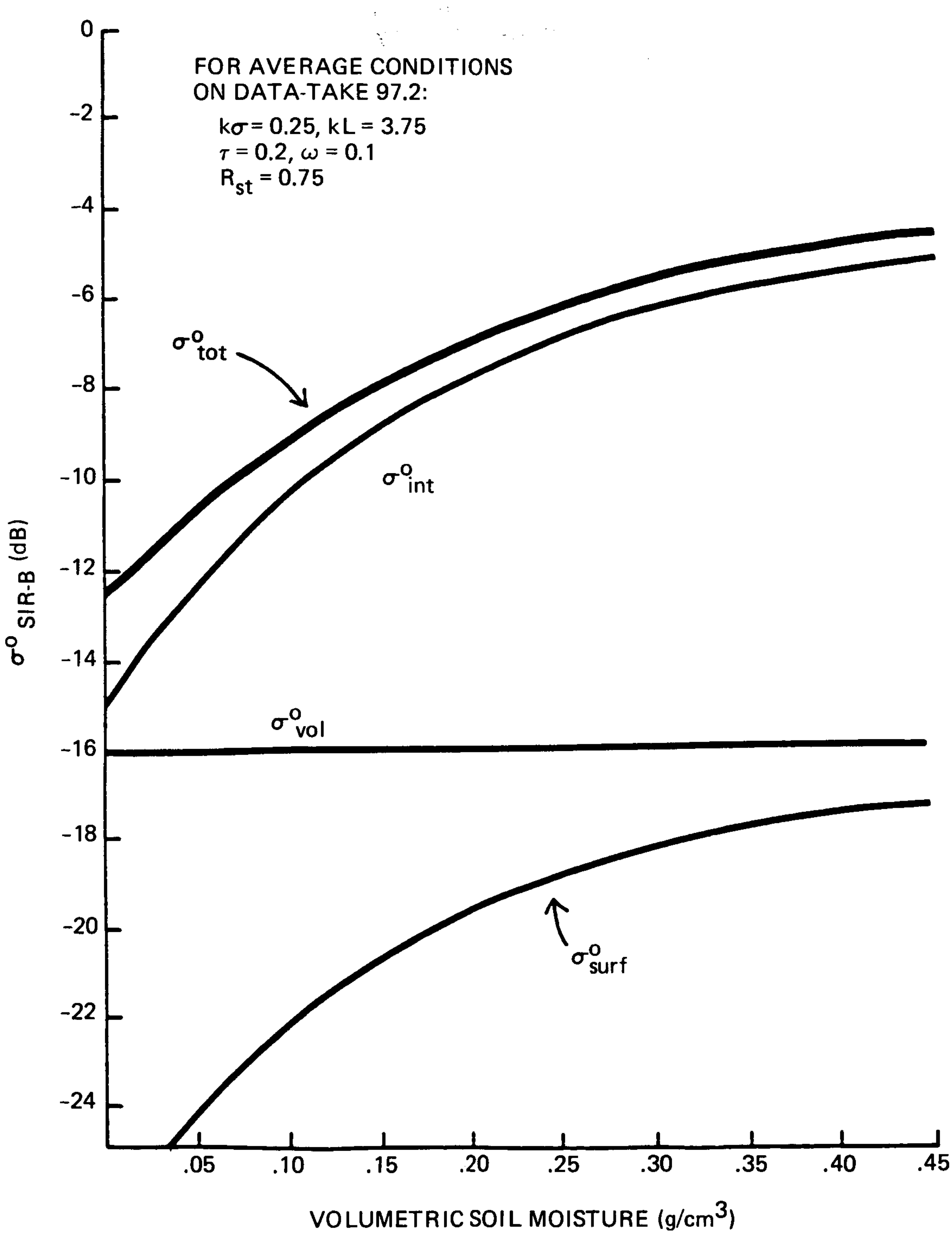
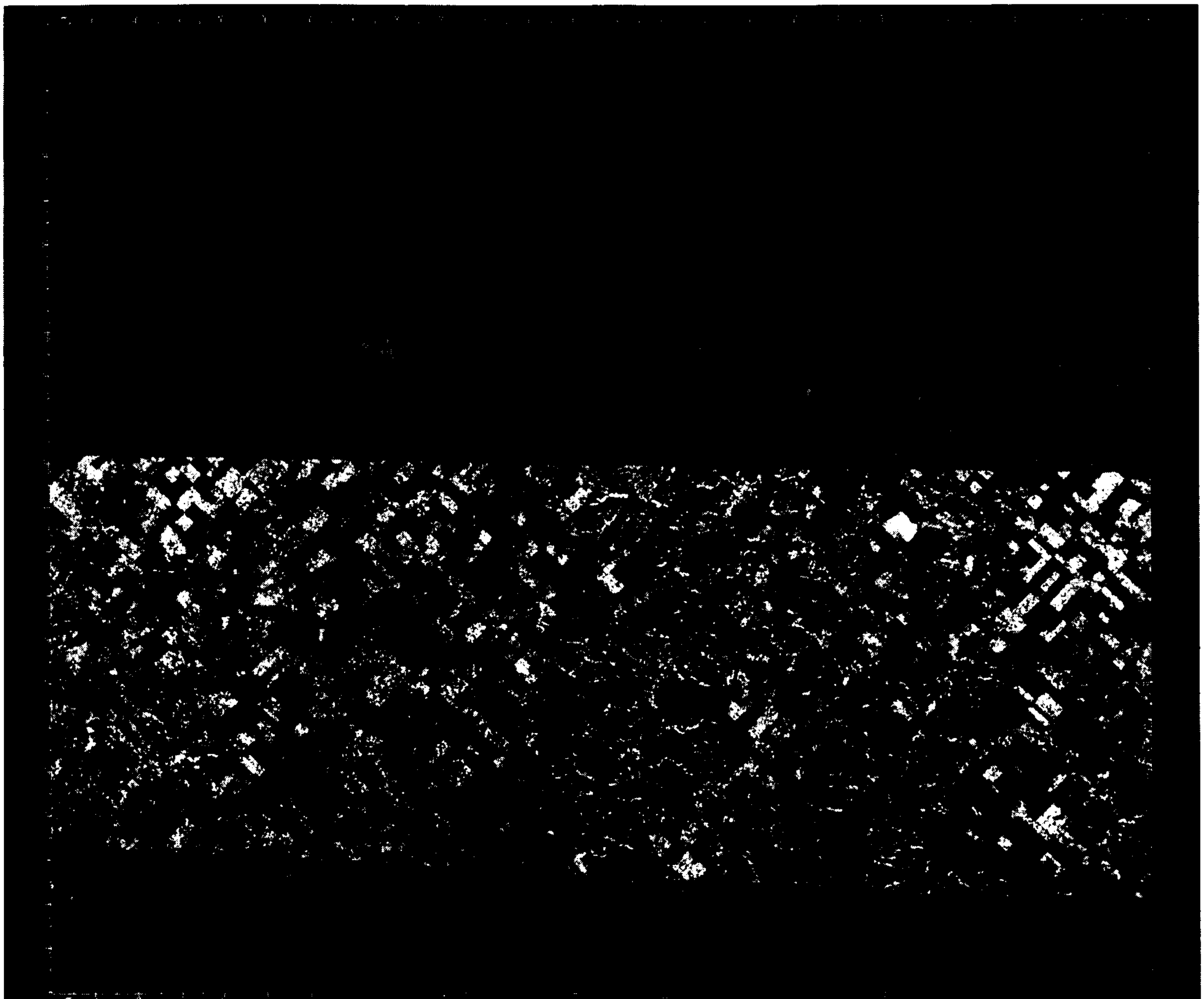


Figure 3. Backscattering contributions of the soil surface, corn canopy, and surface-stalk interactions.



COLOR	DATA TAKE	DATE	LOCAL TIME	INCIDENCE ANGLE	LOOK DIRECTION
RED	86.1	OCTOBER 10	1:34 PM	59 DEG	NE
GREEN	54.1	OCTOBER 8	2:08 PM	38 DEG	NE
BLUE	38.1	OCTOBER 7	2:25 PM	17 DEG	NE

Figure 4. Color composite of multiangle and multidata SIR-B imagery of the Illinois test site. (This image was orignally produced in color.)

ORIGINAL PAGE IS

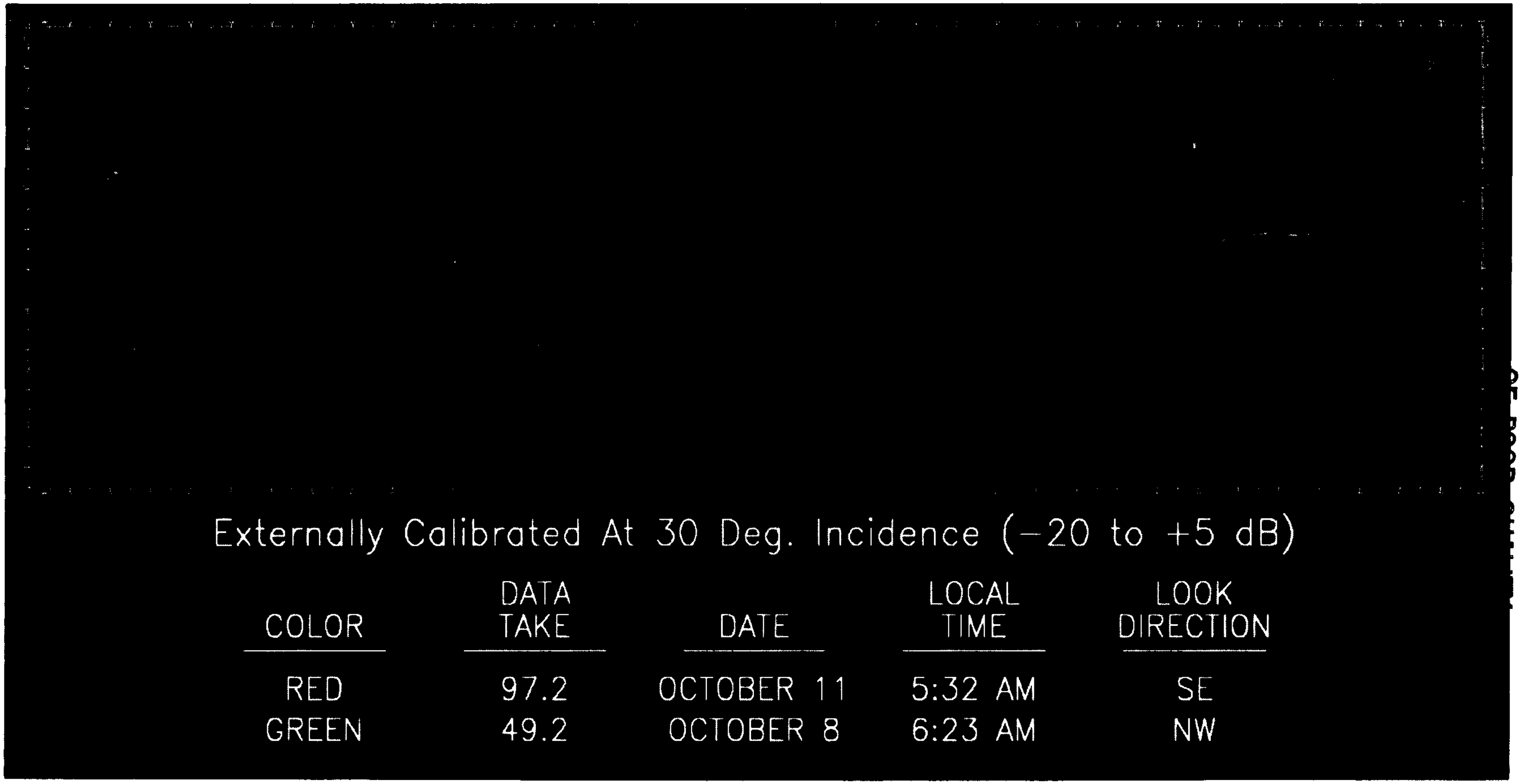


Figure 5(a). Color composite of calibrated SIR-B stereo images at 30° incidence angle. (This image was originally produced in color.)

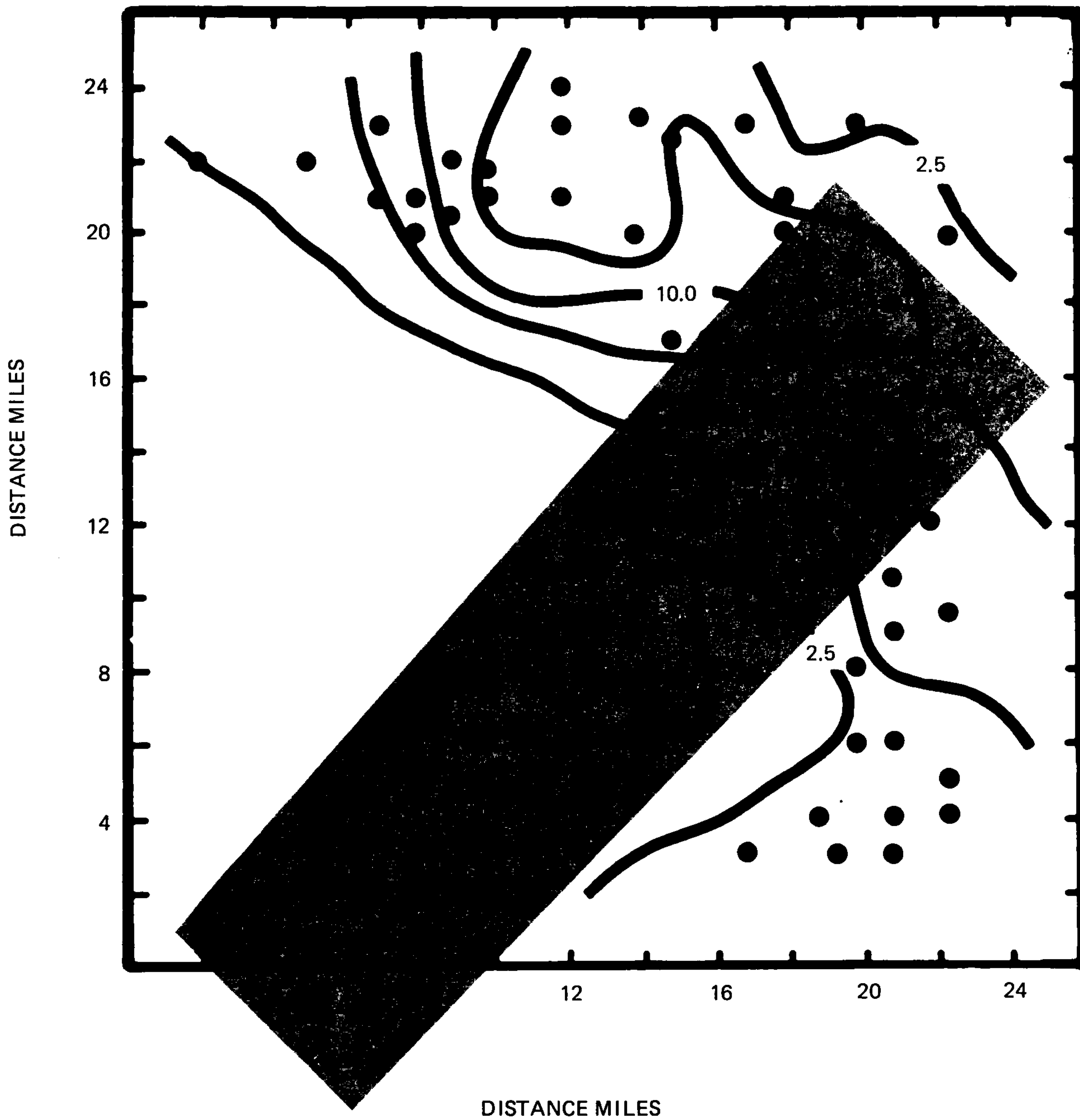


Figure 5(b). Rain gauge locations at Illinois SIR-B test site. Change in calibrated backscatter at 30° incidence over three days and associated cumulative rainfall (in millimeters) on October 9 and 10. Red, yellow, green, and blue correspond to $\Delta\sigma^\circ$ of ≤ -2 dB, ≤ 0 dB, $\leq +4$ dB, and > 4 dB, respectively. (This image was originally produced in color.)